Mechatronics Design Approach for Working Model of Swinging Boat in Amusement Park

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Abstract

The paper is concerned with mechatronics approach to design and construct a working model of a "Kora-kora" Swinging Boat Ride for educational and entertainment applications based on the study of the actual ride in an amusement park. By constructing a working model of this ride, it is possible to learn and apply mechanical, electrical and programming aspects to solve similar problems creatively. From the mechanical aspect, it clearly represents pendulum movement. From electromechanical and programming systems, the left and right swing movement of the ride is driven by a DC motor under the control of a microcontroller. The sensor used to detect the swing of the boat is an optical encoder. From the passenger point of view, riding a swinging boat gives excitement and unique sensation due to the variation of gravitational acceleration. This gravitational acceleration is observed by using accelerometer to detect and measure the angular acceleration of the boat. Finally, the whole system is integrated and tested to evaluate its performance which proved to be very similar to the actual system.

Keywords

Swinging Boat; Mechatronic Approach; Working Model; Accelerometer, Embedded Controller

Introduction

DUFAN (Dunia Fantasi) is a famous theme park in North Jakarta. It has many rides and attractions, and one of the most famous rides is "Kora-kora". Most of the amusement parks in the world have this kind of ride. The original name of Kora-kora is "Swinging ship". The Swinging ship manufacturers produce many types of rides based on the passengers capacity. Those manufactures are Fabbri (www.fabbrigroup.com), Huss rides (www.hussrides.com).

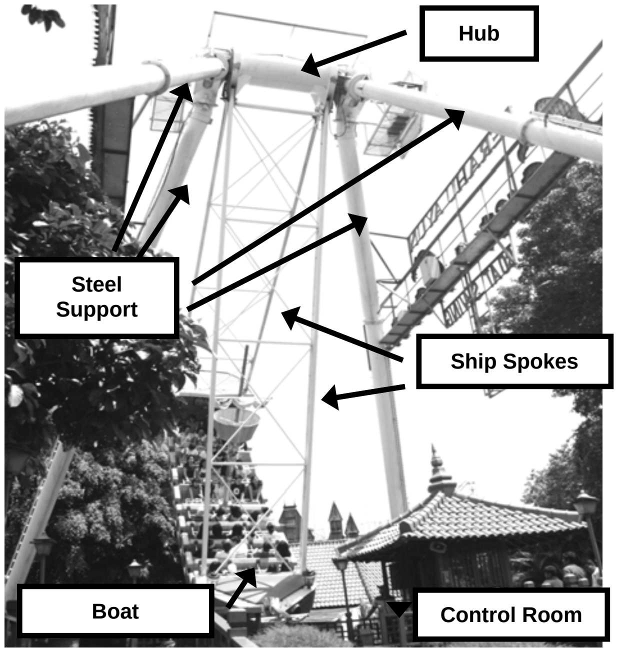


FIG. 1 THE ORIGINAL KORA-KORA RIDE IN THE PARK

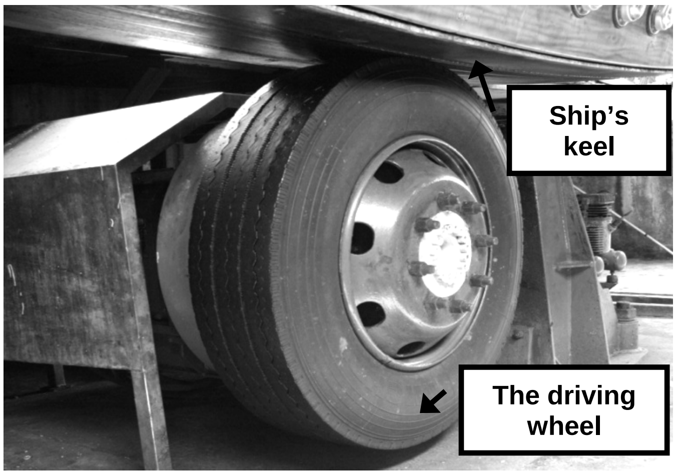


FIG. 2 DRIVING WHEEL UNDER THE BOAT

By studying the system of a swinging boat in Dunia Fantasi, the writer reveals that The Swinging ship is exactly a nicely designed mechatronics product which gives sensational feelings to its passengers. It is also serves as an educational tool to see many principles of physics, mechanics, electronics and control which work together in a controlled and synergetic way. This is a

good start to create a working model of the swinging ride by employing mechatronics approach. Mechatronics design practices have been reported in many sources [1–6].

Fig. 1 is the picture of the actual system, while Fig. 2 shows the main driving wheel and mechanism at time when the bottom of the boat touches it to create boat movement back and forth.

Mechatronics Design Approach

System Design Overview and Work Breakdown Stucture

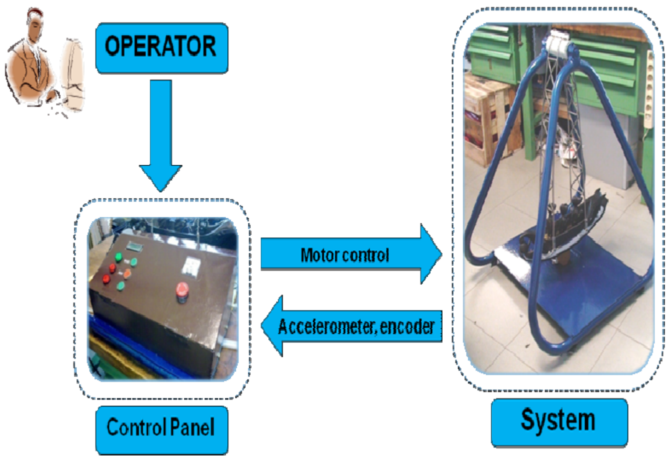


FIG. 3 SYSTEM DESIGN OVERVIEW

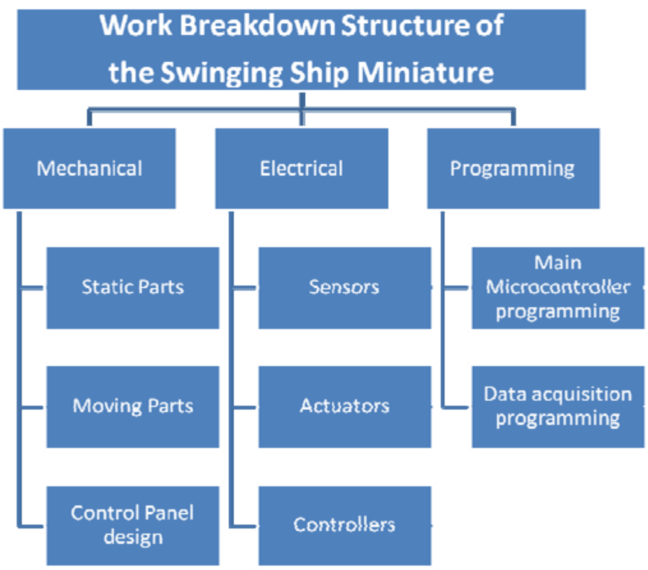


FIG. 4 SYSTEM WORK BREAKDOWN STRUCTURE

The system design overview is illustrated as in Fig 3. The swinging boat design is then represented in a system work breakdown structure (SWBS) and given in Fig. 4.

The operator of will communicate with the system through the control panel user interface. The microcontroller and the circuit inside the control panel will give signal to rotate the motor so the miniature boat will swing back and forth.

Subsystem Work Breakdown Stuctures

Next step of the design in to create the WBS of each subsystem. Fig. 5 shows the result of the more detailed Mechanical subsystem WBS. It is distinguished between static and moving parts of the structure. As the control panel is a separate design, it is assumed as a separate design.

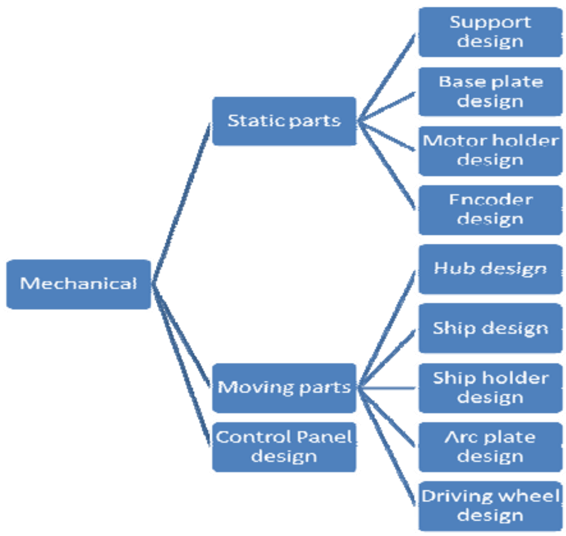


FIG. 5 COMPLETE MECHANICAL WORK BREAKDOWN STRUCTURE

Next is the electrical and programming control work breakdown structure. Its WBS is shown in Fig. 6.

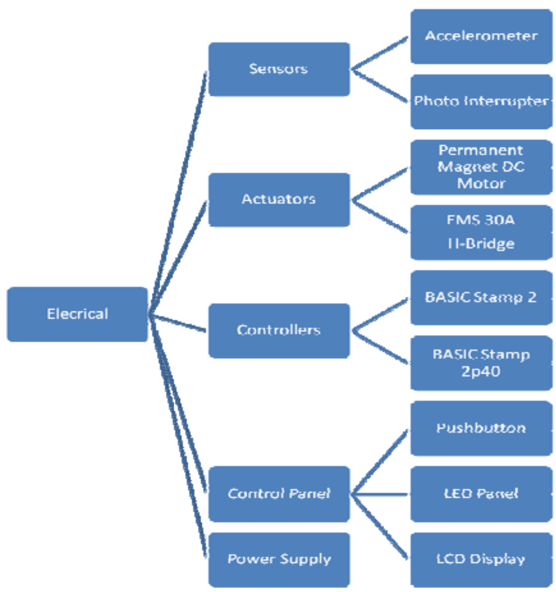


FIG. 6 COMPLETE ELECTRICAL WORK BREAKDOWN STRUCTURE

Detailed Design and Fabrication

After the system and subsystems WBS are derived based on the requirement and observation, then each part is designed, produced and assembled. In this paper, the writer will only focused on the most important part from the mechatronics point of view. Those are the driving mechanism where the mechanical, electrical, and programming control subsystem must be adjusted and synchronized to generate the required movement of the boat, both acceleration and deceleration. The driving wheel assembly is given in Fig. 7, showing the wheel, the bottom of the boat, the spring mechanism and some wiring to its motor and encoder.

At the driving wheel mechanism, the most important thing is to keep the wheel pushing the arc. By this pushing action, the driving wheel is able to transfer kinetic energy from the motor to move the ship back and forth. On fig. 7, the wheel kept pushing the arc by means of mechanical spring under the motor holder. The motor holder is bolted at a fixed door hinge, so the motor holder can move in an upward and downward direction. When the ship is at a full swing position, the driving wheel will not be pushed downward by the arc plate. Meanwhile, the driving wheel will be pushed downward during a full stop.

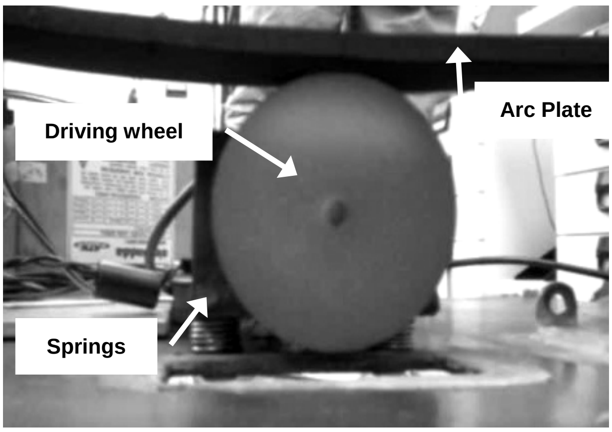


FIG. 7 THE ACTUAL DRIVING MOTOR AND ITS DRIVING WHEEL

Control Algorithm

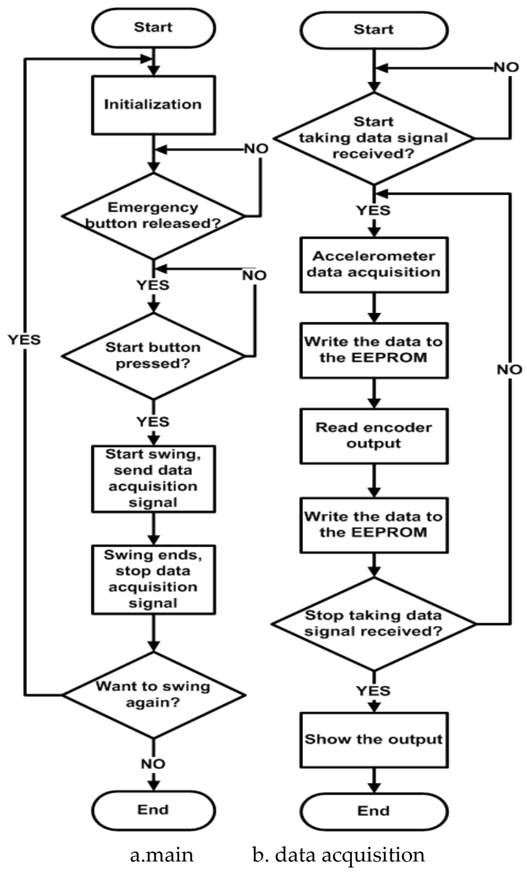
For the control system, the flowcharts are designed as follows, where the main flowchart is given in Fig. 8.a. Fig. 8.b. is for data acquisition of acceleration of the swing.

One additional flowchart worth mentioning in this paper is how the swinging patterns of the boat can be generated with embedded microcontroller. It is given in Fig. 9. Start and stop signals both in clockwise and anti-clockwise directions are programmed in such way to create oscillating pendulum.

On acceleration, the driving wheel spins faster in the swing direction of the boat than the boat movement, until certain maximum high of swing is reached. In the contrary, on deceleration, the driving wheel spins slower in the swing direction of the boat than the boat movement, until both driving wheel and boat stop. This is when the passenger can leave or board the boat in the actual amusement parks.

Measurement Results

As already given in the flowchart 8.b, one of the interesting data, apart from the control system, is the gravitational variation which is experienced by the passengers on the boat. By doing this experience, the writer want to prove that every passengers on each row of the boat will not feel the same gravitational acceleration. This experiment is achieved by placing a 3-axis accelerometer in the desired sitting position, both in real and miniature swinging ship.



a.main b. data acquisition

FIG. 8 THE MAIN (A) AND DATA ACQUISITION (B) FLOWCHARTS

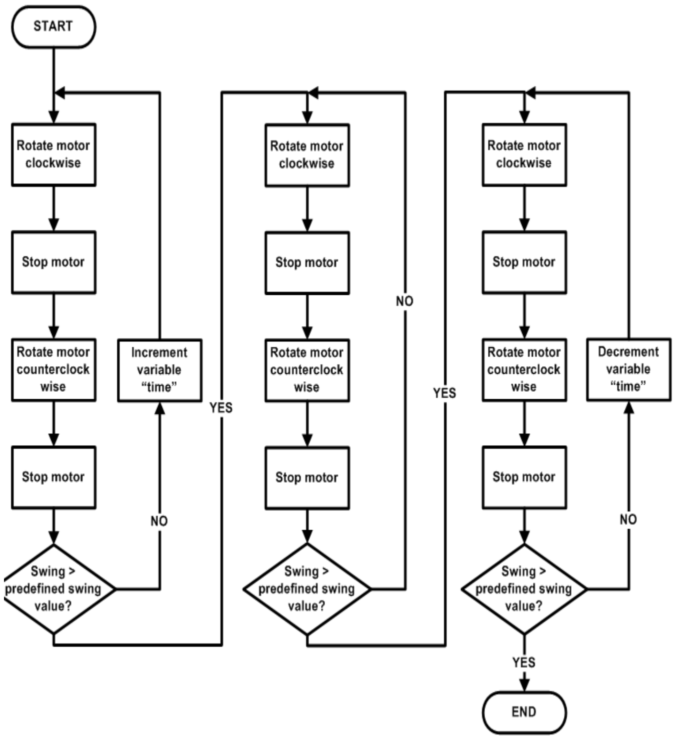


FIG. 9 DC MOTOR CONTROL FLOWCHART

As can be expected, the biggest gravitational acceleration variation experienced by the passenger is in the swing direction of the boat. The most uncomfortable, but also in the same time the most sensational, feeling is experienced when the passenger is at the highest point from the ground surface, just before the swinging ship is about to swing back to the opposite direction. At this time, the passengers feel like floating as felt by the stomach churning. Meanwhile, at the lowest position when the passengers are closest to the ground, the boat moves fastest, and the passengers are strongly pushed towards the boat.

To verify this expectation, measurement of the acceleration is focused mostly on the Z-axis that is perpendicular to the seat of each passenger, which is pointing from the boat toward the hub as illustrated in Fig. 1. Here are some results plotted with corresponding sitting position of the passenger on the real swinging boat during movement, as shown in Fig. 10-12. The green rectangle on the boat is the position of the accelerometer on the boat, which corresponds to the sitting position of the passengers. Fig. 10-12 shows two things:

(1) The gravitation graph on each figure shows that the gravitational acceleration on the middle of the ship is different with the gravitational acceleration at the side of the ship. So the sitting rows of the passengers really affects the gravitational acceleration variation experienced by the passengers.

(2) If the passenger sits further away from the center of the boat (Fig. 12 – left), less gravitational acceleration will be experienced by the passengers (less than $0.5g$). Less gravitational acceleration or near-zero acceleration ($0g$) will result in a "free-fall" feelings experienced by the passengers. Eventhough this effects only happens in a several milliseconds, it is enough to create a thrilling effects to the passengers.

The comparison of measured acceleration between actual and model boats is plotted in Fig.13 and both show good agreement in the acceleration experienced depending on the sitting position of the passenger and the position of the boat itself.

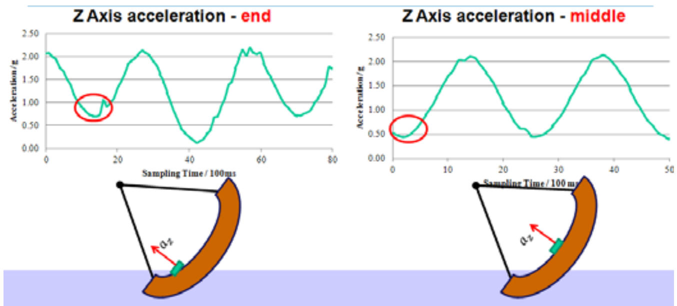


FIG. 10 ACCELERATION MEASURED ON THE REAL SWINGING BOAT,DURING THE LEFT SWINGING POSITION

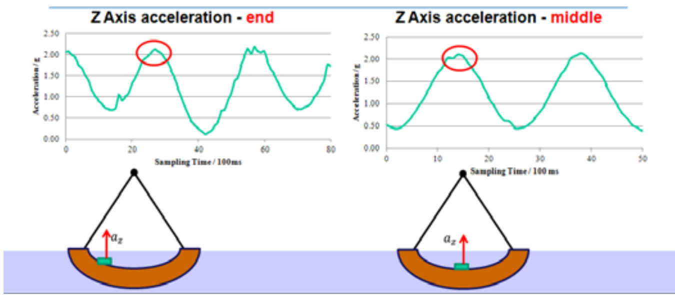


FIG. 11 ACCELERATION MEASURED ON THE REAL SWINGING BOAT,AT THE BOTTOM POSITION DURING SWINGING

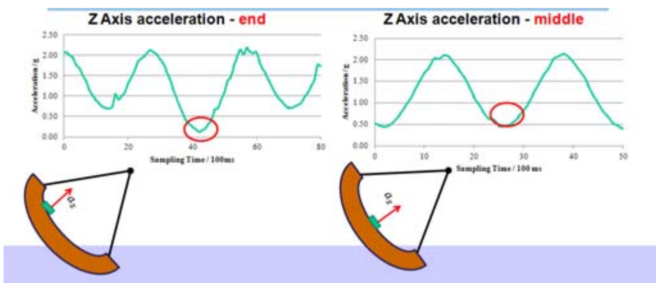


FIG. 12 ACCELERATION MEASURED ON THE REAL SWINGING BOAT, DURING THE LEFT SWINGING POSITION

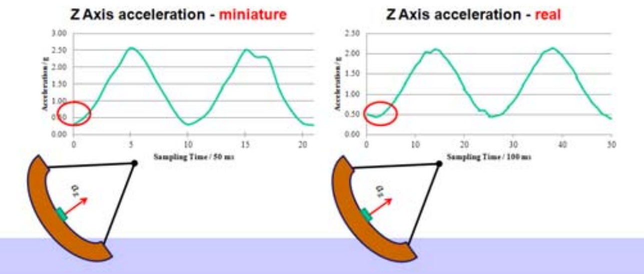


FIG.13 ACCELERATION MEASURED ON THE REAL AND MODEL BOAT

Conclusion

The "Kora-kora" swinging boat miniature is working as desired. The boat can swing back and forth in a normal operation. The control panel as a user interface also has been built to control the movement of the boat. An accelerometer has been installed to analyze the movement of the working model of swinging boat. In general, it is proved that this working model is very similar with the real Swinging ship ride. This miniature can be considered as a useful method for basic physics principles demonstrations and also useful tools to learn mechatronics in term of mechanics, electrics, and control technique.

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He worked previously in a government research center until 2002. In 2003 he spent one year as research scientist and field engineer in oil field with Schlumberger wireline services in the Sahara desert. In 2004 he joined Mechatronics Department at the Swiss German University (SGU) in Indonesia until now as senior lecturer and holds a structural position as director of academic research and community service (ARCS) at SGU from 2010. His major interest is geared toward embedded systems for mechatronics application where mechanical engineering, electrical engineering, embedded control system / microcontroller are tightly related and integrated. Sensor, Instrumentation, Measurement, Control and all related area of Embedded System Design for Mechatronics are his major interest in both research and teaching. He is a member of IEEE, serves as reviewer and International Program Committee (IPC) member for a number of international conferences. Additionally he is also co-founder and member of editorial board of Journal of Mechatronics, Electrical Power and Vehicular Technology (www.mevjournal.com). Many publications in the related areas are easily searchable in the internet.